# Integration of a Maritime Modeling Capability into the Infrared Sensor Stimulator (IRSS)

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## ABSTRACT

The Office of the Secretary of Defense (OSD), Central Test and Evaluation Investment Program (CTEIP) is tasked with providing a coordinated process for making joint investments in defense test & evaluation (T&E) to offset the challenges presented by declining investments in test assets and increasing test requirements. Under CTEIP sponsorship, the Navy and Air Force are jointly developing three Joint Installed System Test Facility (JISTF) enhancements that are based on dynamic virtual reality simulation technology. The three enhancements are the Infrared Sensor Stimulator (IRSS), Generic Radar Target Generator (GRTG), and Joint Communications Simulator (JCS). These enhancements will provide each ISTF with the capability to simultaneously test multiple avionics and sensor subsystems installed on an aerospace System Under Test (SUT) (e.g. manned and unmanned aircraft) in a ground test environment. The ISTF enhanced test capabilities will be used to evaluate multi-sensor data fusion/correlation and subsystems' interoperability for Infrared Sensors, RADAR, GPS, and Communications and Data Link subsystems.

The IRSS program[1] was previously briefed at the 1997 and 1998[2] GTM&V Conference. This paper addresses the integration of a maritime modeling capability into the IRSS Scene Generation Subsystem (SGS).

The IRSS system is designed to function primarily on commercial-off-the-shelf (COTS) hardware such as the Silicon Graphics (SGI) Onyx2® InfiniteReality graphics computer. The symmetric multiprocessing capability of the SGI Onyx2 computer gives the IRSS system a multi-channel capability for the simulation and rendering of multi-spectral infrared images at high frame rates.

As part of the Infrared Sensor Stimulator (IRSS) development project, Comptek Amherst Systems Inc. is tasked with incorporating the capability to render infrared simulations of the Maritime Combat Environment (MACE). To achieve the requirements associated with the modeling and rendering of surface ships, and the dynamic nature of the ocean background, Comptek Amherst has extracted, modified, and integrated portions of the US Navy's maritime model IRENE within the MACE structure. As a result, IRSS has been provided with the unique capability of rendering surface ships and an ocean background in a real-time high-fidelity IR simulations.

This paper will outline the basic process of the integration of the extracted and reworked portions of IRENE into IRSS and several of the challenges, issues, and solutions that accompanied this task.

**KEYWORDS:** Installed Systems Testing, Infrared Sensors, Scene Simulation, Maritime IR Model

# 1. INTRODUCTION

When creating the IRSS, it became apparent that one of the first sensors to be tested with the system would be the US Navy's AAS-44V FLIR system. In order to ensure that the modeling and simulation capabilities of IRSS would be capable of simulating the type of environment in which the AAS-44V would be used, a requirement was issued for a comprehensive Maritime Combat Environment (MACE) capability to be implemented. There were three main phases to the introduction of a MACE capability into IRSS.

First, the models scheduled for integration into IRSS had to be evaluated for their applicability to MACE. When these models were found to be overall lacking in capability, the second phase became the selection of a suitable model, or set of models, for integration. Third, the selected models had to be integrated into the system.

After briefly reviewing the first two steps outlined above, the paper will focus on the third phase of this process: the actual integration of the selected model(s).

# 2. IRSS MODELING CAPABILITY EVALUATION

When examining whether or not the capabilities of IRSS meet the challenges of MACE, an examination of some of the seminal features of the maritime environment must be made.

The signature modeling of a surface ship can be adequately described by a one dimensional thermal model. This is due mainly to the fact that most of the outside surface of a ship (hull and superstructure) are composed of relatively thin plates. This fact is made even more relevant by the fact that this plate thickness is very small compared to the exposed surface area of these plates. Therefore, thermally, the plates can be treated as one-dimensional, with almost all of the heat transfer being done perpendicular to the main faces of the plates (internal and external).

The speed of a ship is comparable to most wind speeds encountered. This, coupled with the open-air environment of the ocean, make an accurate atmospheric convection calculation important for a good maritime signature model. Additionally, there are many regions of the ship which have very different temperatures during normal operation. The ability to model these "hot regions" within the structure of a ship is critical to correctly modeling the thermal signature of the ship.

The water environment also presents a very unique and special background for a thermal model. As the background provides a significant amount of radiance to a ship, the background must be modeled as accurately as possible.

The ground vehicle model PRISM and the aircraft model SPIRITS are scheduled for integration into the IRSS. These two models were chosen because of their widespread acceptance in the IR modeling community, and their satisfactory performance in regard to functionality. Both models excel in their respective areas of modeling, however they are not suitable for MACE.

PRISM is a detailed 3D thermal signature model used for temperature/radiance calculations of ground-based vehicles. In this modeling realm, a three-dimensional conduction/convection model is necessary due to the thick nature of the plates making up the exterior of the vehicle. While this feature is certainly not something that is bad in a one-dimensional thermal situation, it is unnecessary.

PRISM does not account for the background environment in a way satisfactory for the maritime environment. The method it employs is one of a general background radiance, which is insufficient when dealing with the large effects of solar glint on the sea surface.

SPIRITS is also not up to the maritime modeling task. The model deals with aircraft flying through the atmosphere, not a condition where wind-driven thermal convection is critical. Consequently, the convection modeling capability of SPIRITS is somewhat lacking. Also, the manner in which internal thermal regions are handled is not very transparent, a key issue as the feature is very important to maritime modeling.

Given these considerations, it was decided that investigation of existing maritime signature models had to be undertaken to determine whether an existing model could be incorporated into IRSS, or if a new model would have to be developed from scratch.

# 3. SELECTION OF A MARITIME MODEL

The investigation of existing maritime models led to two main candidates upon which to base the modeling capability: NTCS/SHIPIR and IRENE. The former was created and maintained by W.R. Davis Engineering, Ltd. Of Ontario, Canada. This model not only calculates the thermal and radiometric properties of a ship in its environment, but it also is capable of simulating complete missile engagements between the ship and a variety of anti-ship missiles. The features important for a complete missile engagements between the ship and a variety of anti-ship missiles. The features important for a complete maritime model are included in this model, making it an excellent candidate. In addition, this model has been accepted as the standard NATO maritime model under RSG.5.

The second model considered, IRENE, is a model developed and maintained by the US Navy at its Naval Surface Warfare Center (NSWC) Carderock Division in Bethesda, Maryland. It also contains the salient features necessary in a signature model for applicability to the maritime environment

Both models are excellent candidates, and either model would have been sufficient to accomplish the MACE modeling goals. The decision was based on integration ease and the fact that the time available for the work to be done was relatively short. While there would not have been a problem working with the team at W.R. Davis, there would have been more issues to resolve with SHIPIR than with IRENE. Also, as IRENE is a US Navy model developed under a US Navy contract, greater control was available to influence the integration effort.

# 4. INTEGRATION

## *4.1 INTEGRATION SCHEME*

### *4.1.1 Phase I*

The actual integration scheme for MACE was a three-part effort (see figure 1). The first phase involved most of the work on the creation of the new signature module code itself, and was carried out at NSWC Carderock. A new thermal signature module, derived from IRENE, was written for IRSS. In the past, the model had accepted 2 files for each ship it processed – a geometry file and a separate file containing the radiometric properties of the paints and materials used on the ship. For this effort, these two files were concatenated into one file. This work made the information needed by IRSS more accessible.

The second part of this phase was to make background data (ocean surface radiance values) available to IRSS. This involved the implementation of a way to make the background radiance calculations of the background model consistent with the data used to thermally process the ship.

A major concern was the method to be used in rendering the ocean background. One feature of most maritime models is that while the ocean surface would be accounted for in the radiometric calculations, the information would not be retained for rendering. This background information is needed by IRSS.

A separate ocean surface background model based on the model KELSEA, developed by the Naval Research Laboratory, is used for rendering backgrounds. This model uses a ray-tracing algorithm to determine the apparent radiance of the sea surface based on look angle, sun position and observer altitude. This model was modified to write out the sea surface radiance texture maps (SSRTMs) which are used by IRSS.

The actual rendering of the background is done through the use of the IRSS radiance map rendering capability. The radiance of the ocean surface is calculated in a square grid fashion. The squares comprising this grid can be either 1m or 5m on edge and are 512 x 512 grids. The resultant radiance maps are therefore 512m x 512m or 2560m x 2560m in size, respectively. These grids are then tiled across a flat-polygon ocean surface background appropriately, depending on the size of the background used.

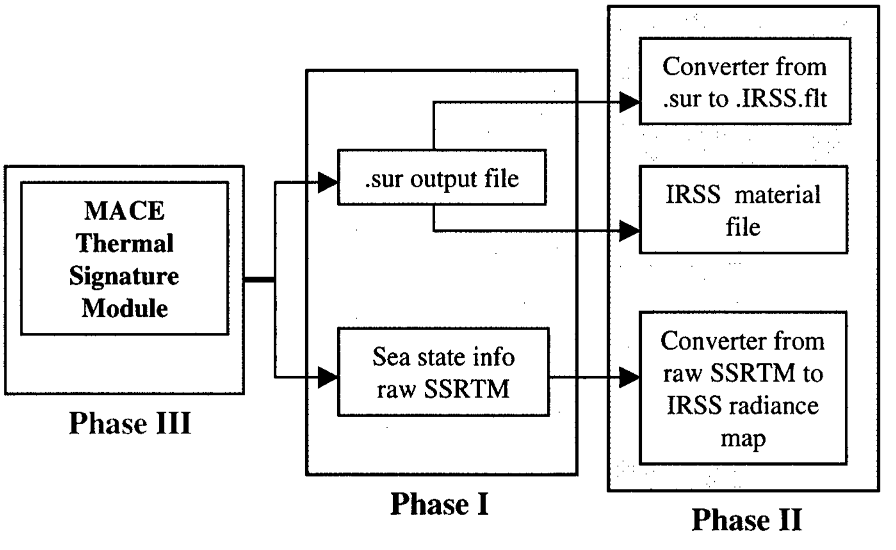


Figure 1. Basic IRSS/MACE Integration Scheme.

*4.1.2 Phase II*

As shown in figure 1, the next part of the overall effort (carried out at Comptek Amherst Systems in Buffalo, NY) involved the creation of a file converter. The converter extracted the necessary information from the *.sur files (the modified IRENE output file) and entered them into IRSS.flt (OpenFlight) format, which is the three-dimensional geometry format used in IRSS. This work was facilitated by the use of the Application Programmable Interface (API) provided with Multigen-Paradigm's modeling program. The API allows for fast and easy access to the OpenFlight file format, making the conversion a relatively simple task.

Also part of Phase II was the conversion of the radiance data produced by the KELSEA-based sea surface model into a format usable by IRSS. The radiance data was in a 16-bit, 256 color grayscale format, which was converted into Silicon Graphics .bw texture format. This texture was then rendered as a radiance map, with atmospheric attenuation and path radiance calculated on a pixel-by-pixel basis.

A related task was the creation of a material file for IRSS, containing the radiometric properties of the paints and materials of the ship to be rendered. As previously stated, IRENE at one point used a separate file for the materials used on the ship. This was incorporated in the actual geometry file of the ship itself. The IRSS converter, which in turn creates a geometry file in OpenFlight format, processes this file and a material file for each material and/or paint used on the ship.

*4.1.3 Phase III*

Phase III involved some of the first work in the project, but it was actually finished last. It consisted of the complete rewriting of the IRENE thermal module, making it, in effect, a completely new thermal model for inclusion in IRSS.

*4.1.4 Phase IV*

Not depicted in figure 1 is Phase IV of the integration effort. This part mainly involved the creation of a user-friendly front-end for MACE. The current method of user interaction with the MACE thermal signature module is a call through a UNIX command-line script. This script processes the desired atmospherics and environmental information, selects the ship model to be processed, and calls the actual signature module. While workable, a more user-friendly graphical interface has been proposed for the fourth integration stage. Currently, it is considered a future upgrade issue. It is important to note, however, that there is no functionality lost by not completing this work, as it is basically an ease-of-use issue.

*4.2 EXECUTION OF INTEGRATION SCHEME*

The work at NSWC Carderock (Phases I and III) went very well. The Carderock team stayed in close contact with the Comptek Amherst team, making it easy for any issues that arose during the work to be resolved quickly and to everyone's satisfaction. This close cooperation led to the saving of a great deal of time and effort, as little time was spent doing work that was later thrown away.

This made the reworking of the input file format and creation of the new signature module very smooth.

Phase II was similarly straightforward for the Comptek Amherst Systems team. The task of creating the file converter, as mentioned above, was completed very quickly due to the fact that the MultiGen's *Creator* Plug-In Tools API gives the programmer fast and easy access to the OpenFlight format.

## 5. RESULTS

Depicted in figures 2 through 7 are some examples of images rendered by IRSS using MACE-generated ships and ocean surface textures. The exact details of each screen capture's contents are given in the caption for each For all images, the sensor is a 256 x 256 staring LWIR array with a 10° x 10° field of view, and white is hot.

In general, the results are very satisfactory. The ships displayed in the images are actually two renderings of the same ship facing in nearly opposite directions. This was done to illustrate (within the limitations of graphical reproduction) the effect of sun position on thermal signature of the ship. The atmosphere used in the rendering is a clear atmosphere – therefore there is little attenuation of the targets and ocean surface texture as a function of distance from the sensor.

A few important notes should be made about the ocean surface texture. Each texture is created based on a single look angle. Naturally, during the course of a scenario, the look angle of the sensor can change dramatically. This limitation is an important one, as it places a limit on the realism of the ocean background. A dynamically updated series of textures is a possibility for future capability, as this would increase the accuracy of the rendered image. This need can be through appropriate extensions to the texture-paging scheme of IRSS.

A fact worth mentioning is the almost uniform appearance of the ships in these figures, aside from the solar heating. There was no attempt to create accurate hot part information for these particular ships as sensitive data would be needed for such a task. Tests indicate expected results when using realistic heated compartments in a ship model.

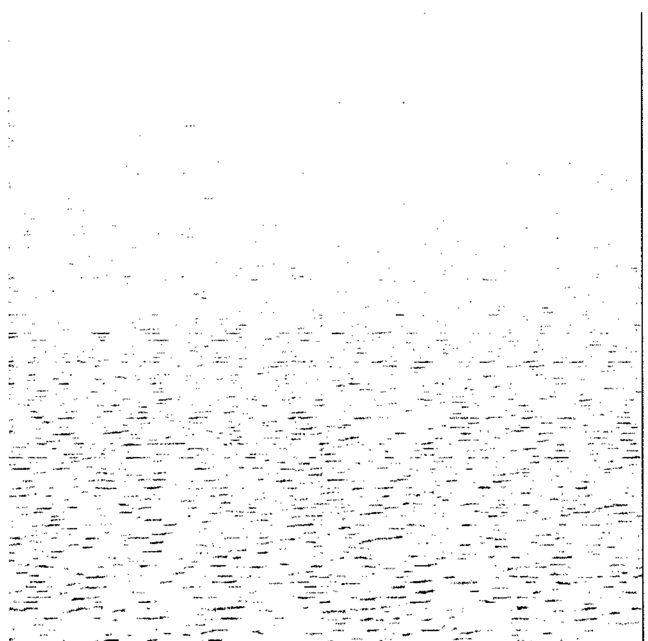

Figure 2. This image is a snapshot of the ocean surface texture at 1m resolution and a sea state of 2. The sensor altitude is ~1200m with a look angle of –10°.

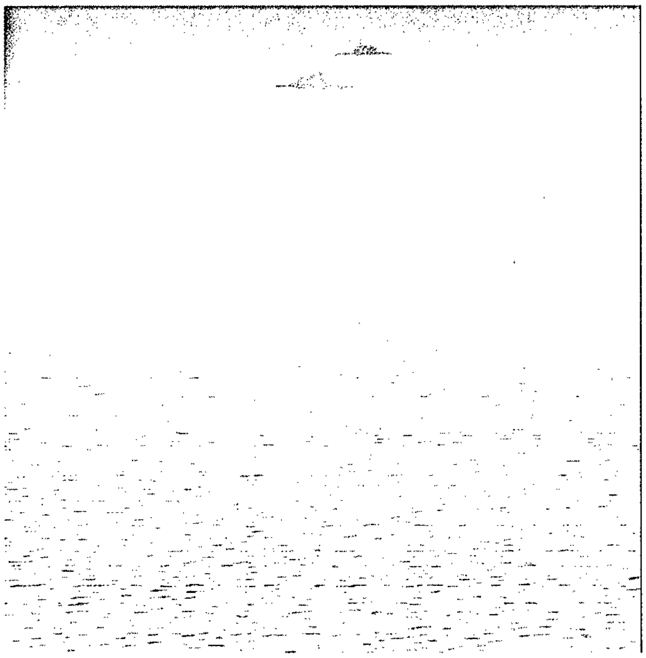

Figure 3. The ocean surface texture is 1m resolution and sea state 2. The sensor altitude is ~1225m with a look angle of –5°. Ranges to the two ships are 2650m and 3600m.

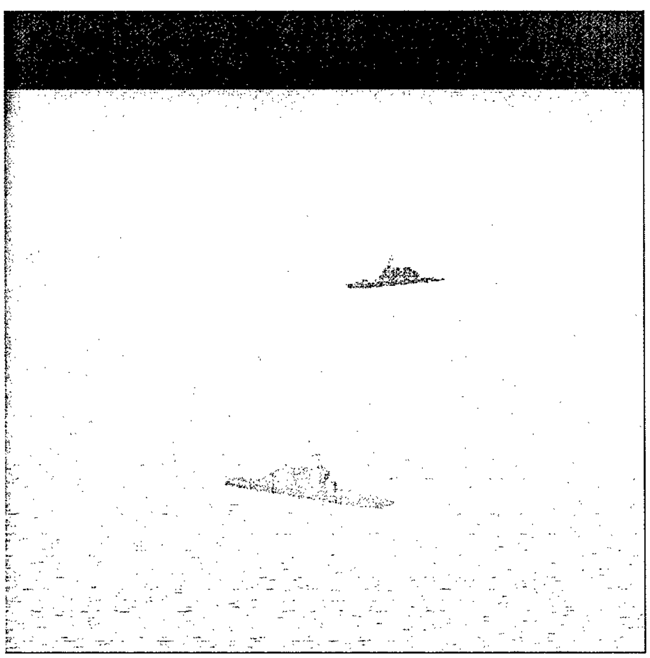

Figure 4. The ocean surface texture is 1m resolution and sea state 2. The sensor altitude is ~1365m with a look angle of –5°. Ranges to the two ships are 1200m and 2150m.

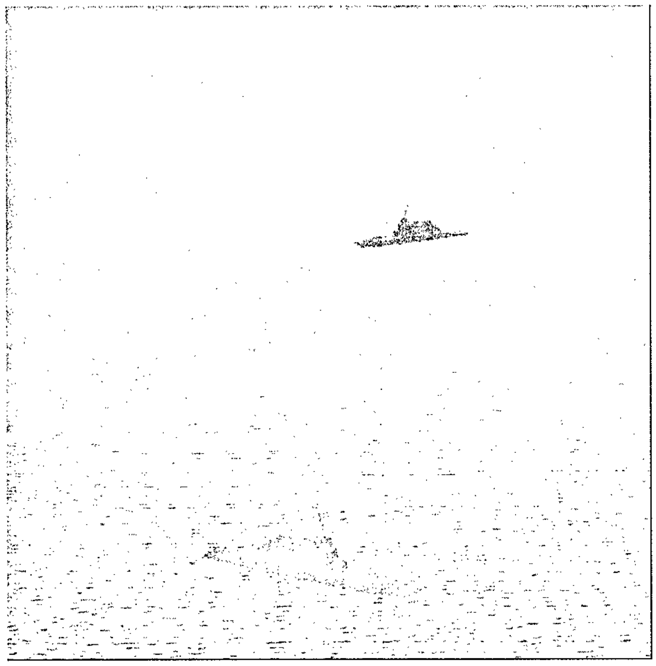

Figure 5. The ocean surface texture is 1m resolution and sea state 2. The sensor altitude is ~1400m with a look angle of –10°. Ranges to the two ships are 740m and 1560m.

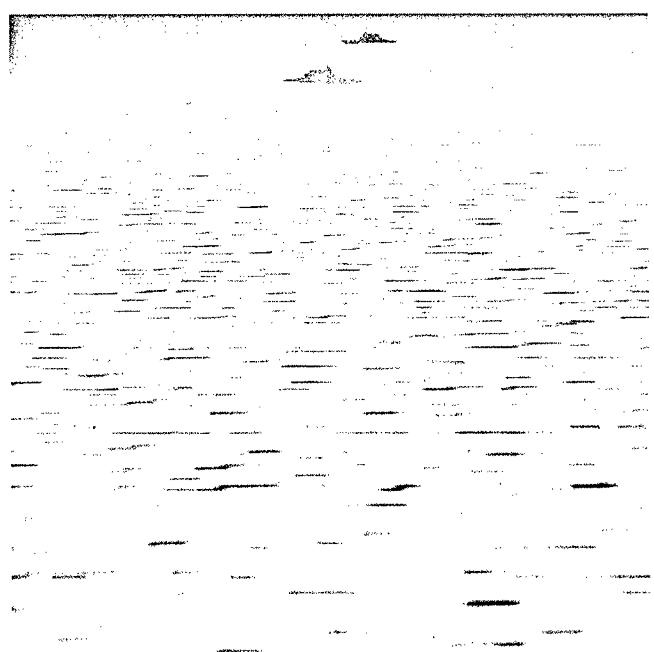

Figure 6. The ocean surface texture is 5m resolution and sea state 2. The sensor altitude is ~1225m with a look angle of –5°. Ranges to the two ships are 2650m and 3600m.

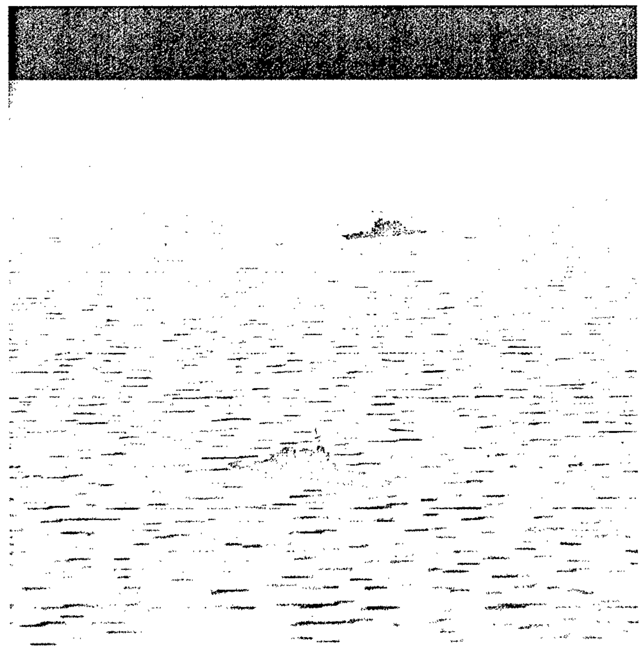

Figure 7. The ocean surface texture is 5m resolution and sea state 2. The sensor altitude is ~1365m with a look angle of –5°. Ranges to the two ships are 1200m and 2150m.

## 6. SUMMARY AND FUTURE

Many of the important issues involved in the integration of a Maritime Modeling Capability into IRSS have been reviewed. There are several lessons, which can be drawn from this success, as well as some important points for further work and improvement.

The use of MultiGen Paradigm's *Creator* for 3D modeling by IRSS allowed the conversion of the .sur geometry format to be extremely smooth. This was critical due to the fact that the entire project, from initial funding to final implementation, lasted only 5 months.

Another important point relates to the cooperation between the developers of IRENE and Comptek Amherst Systems. They were available and willing to participate in the effort. The work would have been far more difficult, and certainly not nearly as straightforward, without their participation. With their knowledge of the workings of an already validated maritime model, the work to be done in the creation of the new signature module was completed very quickly.

There is still room for improvement in the MACE modeling capability of IRSS and studies in this direction have already been undertaken. Features earmarked for future effort are the creation of a wave-height algorithm for sea surface rendering and the inclusion of plumes on the ships themselves. These features have been identified as the main enhancements required to bring the MACE modeling effort closer to its desired level of functionality.

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[2] Joyner, T., "Real-time IR/UV EO Sensor Stimulation," *Proceedings of the Ninth Annual Ground Target Modeling & Validation Conference,* 166-180, Houghton, MI, 1998.

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